Table 68.308(a)

| Programming Resistor ($R_p$) * | Programmed Data Equipment Signal Power Output |
|---|---|
| short | 0 dBm |
| 150 Ohms | -1 dBm |
| 336 Ohms | -2 dBm |
| 569 Ohms | -3 dBm |
| 866 Ohms | -4 dBm |
| 1240 Ohms | -5 dBm |
| 1780 Ohms | -6 dBm |
| 2520 Ohms | -7 dBm |
| 3610 Ohms | -8 dBm |
| 5490 Ohms | -9 dBm |
| 9200 Ohms | -10 dBm |
| 19800 Ohms | -11 dBm |
| open | -12 dBm |

* Tolerance of $R_p$ is ± 1%

(5) Registered one-port and multiport terminal equipment and protective circuitry with provision for through-transmission from ports to other equipment which is separately registered for the public switched network, or ports to other network interfaces.

(i) Registered terminal equipment and registered protective circuitry shall have no adjustments that will allow net amplification to occur in either direction of transmission in the through-transmission path within the 200 - 3995 Hz voiceband that will exceed the following:

Table 68.308(b) Allowable Net Amplification Between Ports (A)(C)(D)(E)

| TO / FROM (E) | Tie Trunk Type Ports | | | Integrated Services Trunk | OPS Ports (2-Wire) (B) | Public Switched Network Ports (2-Wire) | HCC Digital PBX-CO 4-Wire |
|---|---|---|---|---|---|---|---|
| | 2/4-Wire | Subrate 1.544 Mbps Satellite 4W | Subrate 1.544 Mbps Tandem 4W | | | | |
| 2/4-Wire Tie | 0 dB | 3 dB | 3 dB | 3 dB | 6 dB | - | - |
| Subrate 1.544 Mbps Satellite 4W Tie | 0 dB | - | 3 dB | 3 dB | 6 dB | - | - |
| Subrate 1.544 Mbps Tandem 4W Tie | -3 dB | 0 dB | 0 dB | 0 dB | 3 dB | - | - |
| Integrated Services Trunk | -3 dB | 0 dB | 0 dB | 0 dB | 3 dB | - | - |
| RTE Digital | 0 dB | 0 dB | 0 dB | 0 dB | 3 dB | 3 dB | 0 dB |
| RTE (B) PSTN/OPS | -3 dB | -3 dB | -3 dB | - 3 dB | 0 dB | 0 dB | -3 dB |
| OPS (B) (2-Wire) | -2 dB | 1 dB | 1 dB | 1 dB | 4 dB | 4 dB | 1 dB |
| Public Switched Network (2-Wire) | - | - | - | - | 3 dB | 3 dB | - |
| HCC Digital PBX-CO (4-Wire) | - | - | - | - | 3 dB | - | - |

(A) The source impedance for all measurements shall be 600 Ohms. All ports shall be terminated in appropriate loop or private line channel simulator circuits or 600 Ohm terminations.

(B) These ports are for 2-wire on-premises station ports to separately registered terminal equipment.

(C) These through gain limitations are applicable to multiport systems where channels are not derived by time or frequency compression methods. Terminal equipment employing such compression techniques shall assure that equivalent compensation for through gain parameters is demonstrated in the registration application.

(D) Registered terminal equipment and registered protective circuitry may have net amplification exceeding the limitations of this subsection provided that, for each network interface type to be connected, the absolute signal power levels specified in this section are not exceeded.

(E) The indicated gain is in the direction which results when moving from the horizontal entry toward the vertical entry.

(F) Registered terminal equipment or protective circuitry with the capability for through transmission from voiceband private line channels or voiceband metallic channels to other telephone network interfaces shall assure that the absolute signal power levels specified in this section, for each telephone network interface type to be connected, are not exceeded.

(G) Registered terminal equipment or protective circuitry with the capability for through transmission from voiceband private line channels or voiceband metallic private line channels to other telephone network interfaces shall assure, for each telephone network interface type to be connected, that signals with energy in the 2450 to 2750 Hz band are not through transmitted unless there is at least an equal amount of energy in the 800 to 2450 Hz band within 20 milliseconds of application of signal.

(ii) The insertion loss in through connection paths for any frequency in the 800 to 2450 Hz band shall not exceed the loss at any frequency in the 2450 to 2750 Hz band by more than 1 dB (maximum loss in the 800 to 2450 Hz band minus minimum loss in the 2450 to 2750 Hz band plus 1 dB).

(6) *For tie trunk interfaces—Limitation on idle circuit stability parameters.* For idle state operating conditions of registered terminal equipment and registered protective circuitry, the following limitations shall be met:

(i) For the two-wire interface:

$$RL \geq \begin{cases} 9-3^{\frac{\log(f/200)}{\log(2.5)}} \text{ dB} & ; \text{ for } 200 \text{ Hz} \leq f \leq 500 \text{ Hz} \\ 6 \text{ dB} & ; \text{ for } 500 \text{ Hz} \leq f \leq 3200 \text{ Hz} \end{cases}$$

(ii) For the four-wire lossless interface:

$$tl_f \geq \begin{cases} 10-4^{\frac{\log(f/200)}{\log(2.5)}} \text{ dB} & ; \text{ for } 200 \text{ Hz} \leq f \leq 500 \text{ Hz} \\ 6 \text{ dB} & ; \text{ for } 500 \text{ Hz} \leq f \leq 3200 \text{ Hz} \end{cases}$$

$$tl_r > 40 \text{ dB}$$

$$RL_i, RL_o \geq 3 \text{ dB}$$

NOTE: The following definitions apply to return loss requirements:

RL the return loss of 2-wire terminal equipment at the interface with respect to 600 Ohms + 2.16 µF (i.e., $Z_{ref}$ = 600 Ohms + 2.16 µF).

$$RL \triangleq 20 \log_{10} \left| \frac{Z_{PBX}+Z_{ref}}{Z_{PBX}-Z_{ref}} \right|$$

$RL_i$ the terminal equipment input (receive) port return loss with respect to 600 Ohms (i.e., $Z_{ref}$ = 600 Ohms).

$$RL_i \triangleq 20 \log_{10} \left| \frac{Z_{PBX\ (input)}+Z_{ref}}{Z_{PBX\ (input)}-Z_{ref}} \right|$$

$RL_o$ the terminal equipment output (transmit) port return loss with respect

to 600 Ohms (i.e., $Z_{ref}$ = 600 Ohms).

$$RL_o \triangleq 20 \log_{10} \left| \frac{Z_{PBX\ (output)} + Z_{ref}}{Z_{PBX\ (output)} - Z_{ref}} \right|$$

tl the transducer loss between the receive and transmit ports of the 4-wire PBX.

$tl_f$ is the transducer loss in the forward direction from the receive port to the transmit port of the PBX.

$$tl_f \triangleq 20 \log_{10} \left| \frac{I_i}{I_r} \right|$$

where $I_i$ is the current sent into the receive port and $I_r$ is the current received at the transmit port terminated at 600 Ohms.

$tl_r$ is the transducer loss in the reverse direction, from the transmit port to the receive port of the PBX.

$$tl_r \triangleq 20 \log_{10} \left| \frac{I_i}{I_r} \right|$$

where $I_i$ is the current sent into the transmit port and $I_r$ is the current received at the receive port terminated at 600 Ohms.

NOTE: The source impedance of $I_i$ is 600 Ohms

(7) Registered terminal equipment and registered protective circuitry shall provide the following range of dc conditions to off-premises station (OPS) lines.

(i) DC voltages applied to the OPS interface for supervisory purposes and during network control signaling shall meet the limits specified in § 68.306(a)(3)(i).

(ii) DC voltages applied to the OPS interface during the talking state shall meet the following requirements:

(A) The maximum open circuit voltage across the tip (T(OPS)) and ring (R(OPS)) leads for all classes shall not exceed 56.5 volts, and

(B) Except for class A OPS interfaces, the maximum dc current into a short circuit across tip (T(OPS)) and ring (R(OPS)) leads shall not exceed 140 mA.

(8) For connections to 1.544 Mbps digital services, the permissible code words for unequipped Mu-255 encoded subrate channels are limited to those corresponding to signals of either polarity, of magnitude equal to or less than X48, where code word, XN is derived by:

XN = (255 - N) base 2
-XN = (127 - N) base 2

(c) Signal power in the 3995-4005 Hz frequency band

(1) Power resulting from internal signal sources contained in registered protective circuitry and registered terminal equipment (voice and data), not intended for network control signaling. For all operating conditions of registered terminal equipment and registered protective circuitry which incorporate signal sources other than sources intended for network control signaling, the maximum power delivered by such sources in the 3995-4005 Hz band to an appropriate simulator circuit, shall be 18 dB below maximum permitted power specified in paragraph (b) of this section for the voiceband.

(2) Terminal equipment with provision of through-transmission from other equipment. The loss in any through-transmission path of registered terminal equipment and registered protective circuitry at any frequency in the 600 to 4000 Hz band shall not exceed, by more than 3 dB, the loss at any frequency in the 3995 to 4005 Hz band, when measured into an appropriate simulator circuit from a source which appears as 600 Ohms across tip and ring.

(d) *Longitudinal voltage at frequencies below 4 kHz.* The weighted rms voltage* averaged over 100 milliseconds that is resultant of all of the component longitudinal voltages in the 100 Hz to 4 kHz band after weighting according to the transfer function of f/4000 where f is the frequency in Hertz, shall not exceed the maximum indicated under the conditions stated in § 68.308(g).

| Frequency range | Maximum Weighted rms Voltage | Impedance |
|---|---|---|
| 100 Hz to 4 kHz | - 30 dBV | 500 Ohms |

* NOTE: Average magnitudes may be used for signals that have peak-to-rms ratios of 20 dB and less. The rms limitations must be used instead of average values if the peak-to rms ratio of the interfering signal exceeds this value.

(e) *Voltage in the 4 kHz to 6 MHz frequency range-general case - 2-wire and 4-wire lossless interface (except LADC).* Except as noted, rms voltage as averaged over 100 milliseconds at the telephone connections of registered terminal equipment and registered protective circuitry in all of the possible 8 kHz bands within the indicated frequency range and under the conditions specified in subsection (g) shall not exceed the maximum indicated below. For (1)(i) and (2)(i) below, "f" is the center frequency in kHz of each of the possible 8-kHz bands beginning at 8 kHz.

(1) *Metallic Voltage*

(i) *4 kHz to 270 kHz.*

| Center Frequency (f) of 8 kHz Band | Max Voltage in all 8 kHz bands | Metallic Terminating Impedance |
|---|---|---|
| 8 kHz to 12 khz | -(6.4 + 12.6 log f) dBV | 300 Ohms |
| 12 kHz to 90 kHz | (23 - 40 log f) dBV | 135 Ohms |
| 90 kHz to 266 kHz | -55 dBV | 135 Ohms |

(2) *Longitudinal voltage*

(i) *4 kHz to 270 kHz.*

(ii) *270 kHz to 6 MHz.* The rms value of the longitudinal voltage components in the frequency range of 270 kHz to 6 MHz, shall not exceed -30 dBV. This limitation applies with a longitudinal termination having an impedance of 90 Ohms.

| Center frequency (f) of 8 kHz band | Max Voltage in all 8 kHz bands | Longitudinal Terminating Impedance |
|---|---|---|
| 8 kHz to 12 kHz | -(18.4 + 20 log f) dBV | 500 Ohms |
| 12 kHz to 42 kHz | (3 - 40 log f) dBV | 90 Ohms |
| 42 kHz to 266 kHz | -62 dBV | 90 Ohms |

(f) *LADC interface.* The metallic voltage shall comply with the general requirements in (1) below as well as the additional requirements specified in (2) and (3) as stated. The requirements apply under the conditions specified in § 68.308(g). Terminal equipment for which the magnitude of the source and/or terminating impedance exceeds 300 Ohms, at any frequency in the range of 100 kHz to 6 MHz, at which the signal (transmitted and/or received) has significant power, shall be deemed not to comply with these requirements. A signal is considered to have 'significant power' at a given frequency if that frequency is contained in a designated set of frequency bands which collectively have the property that the rms voltage of the signal components in those bands is at least 90% of the rms voltage of the total signal. The designated set of frequency bands must be used in testing all frequencies.

(1) *Metallic voltages - frequencies below 4 kHz.*

(i) *Weighted rms voltage in the 10 Hz to 4 kHz frequency band.* The weighted rms metallic voltage in the frequency band from 10 Hz to 4 kHz, averaged over 100 milliseconds that is the resultant of all the component metallic voltages in the band after weighting according to the transfer function of f/4000 where f is the frequency in Hertz, shall not exceed the maximum indicated below under the conditions stated in section (g).

| Frequency range | Maximum voltage |
|---|---|
| 10 Hz to 4 kHz | +3 dBV |

(ii) *RMS Voltage in 100 Hz bands in the frequency range 0.7 kHz to 4 kHz.* The rms metallic voltage averaged over 100 milliseconds in the 100-Hz bands having center frequencies between 750 Hz and 3950 Hz shall not exceed the maximum indicated below.

| Center frequency (f) of 100-Hz bands | Maximum voltage |
|---|---|
| 750 to 3950 Hz | -6 dBV |

(2) *Metallic Voltages - frequencies above 4 kHz - LADC interface.*

(i) *100-Hz bands over frequency range of 4 kHz to 270 kHz.* The rms voltage as averaged over 100 milliseconds in all possible 100-Hz bands between 4 kHz and 270 kHz for the indicated range of center frequencies and under the conditions specified in § 68.308(g) shall not exceed the maximum indicated below:

| Center frequency (f) of 100-Hz bands | Maximum voltage in all 100-Hz bands |
|---|---|
| 4.05 kHz to 4.60 kHz | 0.5 dBV |
| 4.60 kHz to 5.45 kHz | (59.2 - 90 log f) dBV |
| 5.45 kHz to 59.12 kHz | (7.6 - 20 log f) dBV |
| 59.12 kHz to 266.00 kHz | (43.1 - 40 log f) dBV |

Where f = center frequency in kHz of each of the possible 100 Hz bands.

(ii) *8-kHz bands over frequency range of 4 kHz to 270 kHz.* The rms voltage as averaged over 100 milliseconds in all of the possible 8-kHz bands between 4 kHz and 270 kHz for the indicated range of center frequencies and under the conditions specified in § 68.308(g) shall not exceed the maximum indicated below:

| Center frequency (f) of 8-kHz bands | Maximum voltage in all 8-kHz bands |
|---|---|
| 8 kHz to 120 kHz | (17.6 - 20 log f) dBV |
| 120 kHz to 266 kHz | (59.2 - 40 log f) dBV |

Where f = center frequency in kHz of each of the possible 8-kHz bands.

(iii) *RMS Voltage at frequencies above 270 kHz.* The rms value of the metallic voltage components in the frequency range of 270 kHz to 6 MHz, averaged over 2 microseconds, shall not exceed -15 dBV. This limitation applies with a metallic termination having an impedance of 135 Ohms.

(iv) *Peak Voltage.* The total peak voltage for all frequency components in the 4 kHz to 6 MHz band shall not exceed 4.0 volts.

(3) *Longitudinal Voltage*

(i) *Frequencies below 4 kHz.* The weighted rms voltage in the frequency band from 10 Hz to 4 kHz, averaged over 100 milliseconds is the resultant of all the component longitudinal voltages in the band after weighing according to the transfer function of f/4000, where f is the frequency in Hz, shall not exceed the maximum indicated below under the conditions stated in § 68.308(g).

| Frequency range | Maximum RMS voltage |
|---|---|
| 10 Hz - 4 kHz | -37 dBV |

(ii) 4 kHz to 270 kHz

| Center Frequency (f) of 8-kHz Band | Maximum Voltage in all 8-kHz Bands | Longitudinal Terminating Impedance |
|---|---|---|
| 8 kHz to 12 kHz | -(18.4 + 20 log f) dBV | 500 Ohms |
| 12 kHz to 42 kHz | (3 - 40 log f) dBV | 90 Ohms |
| 42 kHz to 266 kHz | -62 dBV | 90 Ohms |

Where f = center frequency in kHz of each of the possible 8-kHz bands.

(iii) *270 kHz to 6 MHz.* The rms value of the longitudinal voltage components in the frequency range of 270 kHz to 6 MHz shall, averaged over 2 microseconds, not exceed -30 dBV. This limitation applies with a longitudinal termination having an impedance of 90 Ohms.

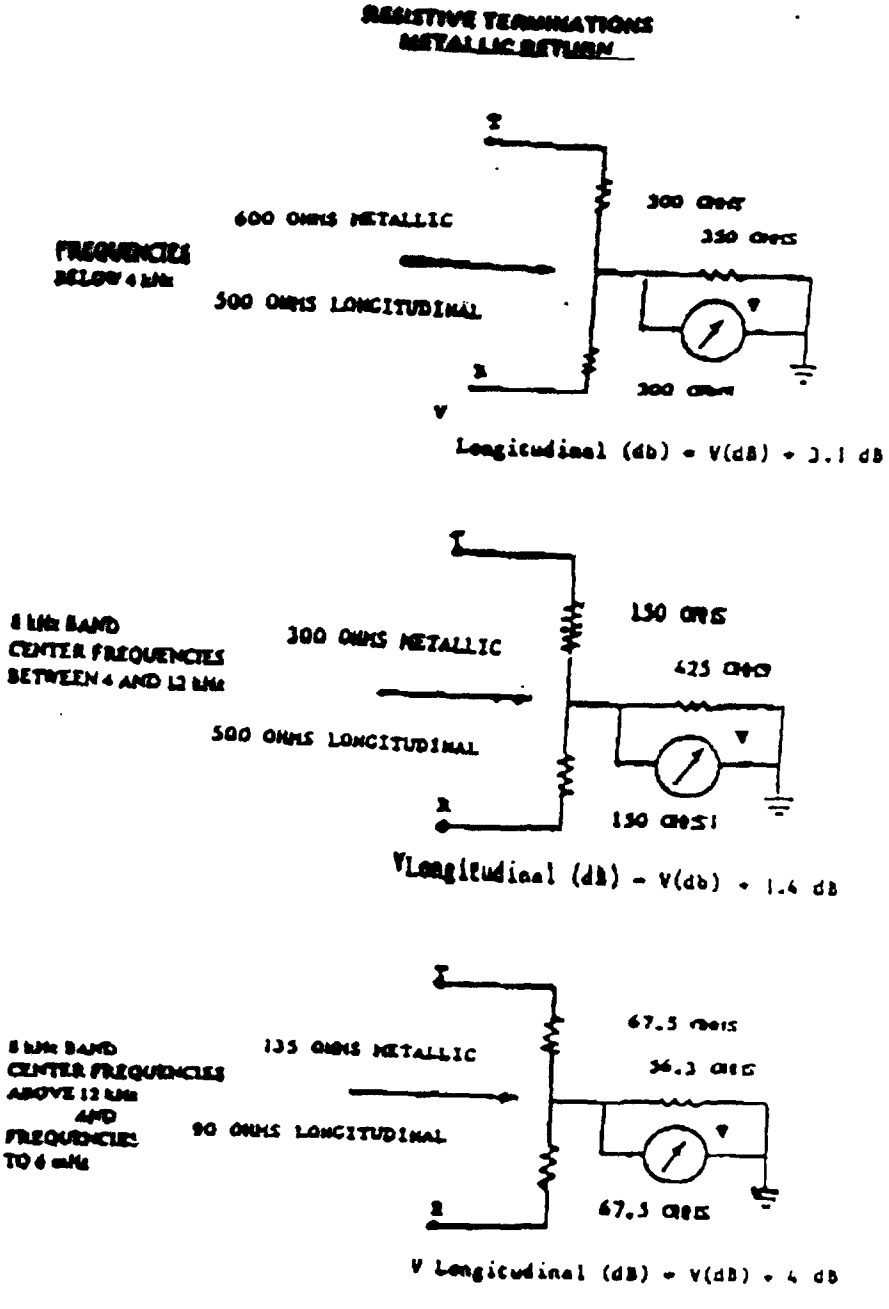



Figure 68.308(a)

(g) *Requirements in paragraphs (d), (e) and (f) apply under the following conditions:*

(1) All registered terminal equipment, except equipment to be used on LADC, and all registered protective circuitry must comply with the limitations when connected to a termination equivalent to the circuit depicted in Figure 68.308(a) and when placed in all operating states of the equipment except during network control signaling. LADC registered terminal equipment must comply with the metallic voltage limitations when connected to circuits of § 68.3(k) and must comply with the longitudinal limitations when connected to circuits of Figure 68.308(a), as indicated.

(2) All registered terminal equipment and registered protective circuitry must comply with the limitations in the off-hook state over the range of loop currents that would flow with the equipment *connected* to an appropriate simulator circuit.

(3) Registered terminal equipment and registered protective circuitry with provision for through-transmission from other equipments shall comply with the limitations with a 1000 Hz tone applied from a 600-Ohm source (or, if appropriate a source which reflects a 600-Ohm impedance across tip and ring) at the maximum level that would be applied during normal operation. Registered protective circuitry for data shall also comply with the tone level 10 dB higher than the overload point.

(4) For registered terminal equipment or registered protective circuitry with non-registered signal source input, such as music on hold, the out of band signal power requirements shall be met using an input signal with a frequency range of 200 Hz to 20 kHz and the level set at the overload point.

(5) Except during the transmission of ringing (§ 68.306(d)) and Dual Tone Multi-frequency (DTMF) signals, LADC registered terminal equipment shall comply with all requirements in all operating states and with loop current which may be drawn for such purposes as loop back signaling. The requirements in § 68.308(f) (1) except in paragraphs (i) and (ii) also apply during the application of ringing. The requirement in § 68.308(d)(2) and the requirements in § 68.308(f)(1)(i) and (1)(ii) apply during ringing for frequencies above 300 Hz and with the maximum voltage limits raised by 10 dB. DTMF signals which are used for the transmission of alphanumeric information and which comply with the requirements in § 68.308(f)(1)(i) and in § 68.308(f)(2) or (3) as applicable, shall be deemed to comply with the requirements in § 68.308(f)(1)(ii) provided that, for automatically originated DTMF signals, the duty cycle is less than 50 percent.

(6) LADC registered terminal equipment shall comply with all applicable requirements, except those specified in § 68.308(f)(1)(i) and (ii), during the transmission of each possible data signal sequence of any length. For compliance with § 68.308(f)(3)(i), the limitation applies to the rms voltage averaged as follows:

(i) For digital signals, baseband or modulated on a carrier, for which there are defined signal element intervals, the rms voltage is averaged over each such interval. Where multiple carriers are involved, the voltage is the power sum of the rms voltages for the signal element intervals for each carrier.

(ii) For baseband analog signals, the rms voltage is averaged over each period (cycle) of the highest frequency of the signal (3 dB point on the spectrum). For analog signals which are modulated on a carrier (whether or not the carrier is suppressed), it is averaged over each period (cycle) of the carrier. Where multiple carriers are involved, the voltage is the power sum of the rms voltage for each carrier.

(iii) For signals other than the types defined in § 68.308(g)(6)(i) and (ii) of this section, the peak amplitude of the signal must not exceed +1 dBV.

(7) Equipment shall comply with the requirements in § 68.308(f)(1)(i) and (ii) during any data sequence which may be transmitted during normal use with a probability greater than 0.001. If the sequences transmitted by the equipment are application dependent, the user instruction material shall include a statement of any limitations assumed in demonstrating compliance of the equipment.

(8) In addition to the conditions specified in (5) of this section, LADC registered terminal equipment which operates in one or more modes as a receiver, shall comply with requirements in § 68.308(f)(3) with a tone at all frequencies in the range of potential received signals and at the maximum power which may be received.

(h) *Interference limitations for transmission of bipolar signals over digital services.*

(1) *Limitations on Terminal Equipment Connection to Subrate Digital Services.*

(i) *Pulse repetition rate.* The pulse repetition rate shall be synchronous with 2.4, 3.2, 4.8, 6.4, 9.6, 12.8, 19.2, 25.6, 56.0, 64 or 72 kbps per second.

*(ii) Template for maximum output pulse.* When applied to a 135 Ohm resistor, the instantaneous amplitude of the largest isolated output pulse obtainable from the registered terminal equipment shall not exceed by more than 10% the instantaneous voltage defined by a template obtained as follows: The limiting pulse template shall be determined by passing an ideal 50% duty cycle rectangular pulse with the amplitude/pulse rate characteristics defined in Table 68.308 (c) through a single real pole low pass filter having a cutoff frequency in Hertz equal to 1.3 times the bit rate. For bit rates of 2.4, 3.2, 4.8, 6.4, 9.6 and 12.8 kbps, the filtered pulses

shall also be passed through a filter providing the additional attenuation in Table 68.308 (d).

Table 68.308(c) - Driving Pulse Amplitude

| Line Rate (kbps) | User Data Rate (R) (kbps) | Amplitude (A) (volts) |
|---|---|---|
| 2.4 | 2.4 | 1.66 |
| 3.2 | 2.4 with SC* | 1.66 |
| 4.8 | 4.8 | 1.66 |
| 6.4 | 4.8 with SC* | 1.66 |
| 9.6 | 9.6 | 0.83 |
| 12.8 | 9.6 with SC* | 0.83 |
| 19.2 | 19.2 | 1.66 |
| 25.6 | 19.2 with SC* | 1.66 |
| 56 | 56 | 1.66 |
| 72 | 56 with SC* | 1.66 |
| 72 | 64 | 1.66 |

* SC: Secondary Channel

Table 68.308(d) - Minimum Additional Attenuation

| Line Rate (R) (kbps) | Attenuation in Frequency Band 24-32 kHz (dB) | Attenuation in Frequency Band 72-80 kHz (dB) |
|---|---|---|
| 2.4 | 5 | 1 |
| 3.2 | 5 | 1 |
| 4.8 | 13 | 9 |
| 6.4 | 13 | 9 |
| 9.6 | 17 | 8 |

| | | |
|---|---|---|
| 12.8 | 17 | 8 |

The attenuation indicated may be reduced at any frequency within the band by the weighting curve of Table 68.308(e). Minimum rejection is never less than 0 dB; i.e., the weight does not justify gain over the system without added attenuation.

| 24-32 kHz Band | 72-80 kHz Band | Attenuation Factor dB |
|---|---|---|
| 24 | 72 | -18 |
| 25 | 73 | - 3 |
| 26 | 74 | - 1 |
| 27 | 75 | 0 |
| 29 | 76 | 0 |
| 29 | 77 | 0 |
| 30 | 78 | - 1 |
| 31 | 79 | - 3 |
| 32 | 80 | -18 |

Table 68.308(e)
Attenuation Curve

(iii) *Average power.* The average output power when a random signal sequence, (0) or (1) equiprobable in each pulse interval, is being produced as measured across a 135 Ohm resistance shall not exceed 0 dBm for 9.6 and 12.8 kbps or +6 dBm for all other rates shown in Table 68.308(b).

(iv) *Encoded analog content.* If registered terminal equipment connecting to subrate services contains an analog-to-digital converter, or generates signals directly in digital form which are intended for eventual conversion into voiceband analog signals, the encoded analog content of the digital signal must be limited. The maximum equivalent power of encoded analog signals for other than live voice as derived by a zero level decoder test configuration shall not exceed -12 dBm when averaged over any 3-second time interval. The maximum equivalent power of encoded analog signals as derived by a zero level decoder test configuration for

signals intended for network control signaling shall not exceed -3 dBm when averaged over any 3-second interval.

(2) *Limitations on Terminal Equipment Connecting to 1.544 Mbps Digital Services.*

(i) *Pulse repetition rate:*

The free running line rate of the transmit signal shall be 1.544 Mbps with a tolerance of ± 32 ppm., i.e., ± 50 bps.

(ii) *Output pulse templates.* The registered terminal equipment shall be capable of optionally delivering three sizes of output pulses. The output pulse option shall be selectable at the time of installation.

(a) *Option A output pulse.* When applied to a 100 Ohm resistor, the instantaneous amplitude of the largest output pulse obtainable from the registered terminal equipment shall fall within the pulse template illustrated in Figure 68.308 (b). The mask may be positioned horizontally as needed to encompass the pulse, and the amplitude of the normalized mask may be uniformity scaled to encompass the pulse. The baseline of the mask shall coincide with the pulse baseline.

(b) *Option B output pulse.* When applied to a 100 Ohm resistor, the instantaneous amplitude of the output from the registered terminal equipment obtained when Option B is implemented shall fall within the pulse template obtained by passing the bounding pulses permitted by Figure 68.308(b) through the following transfer function.

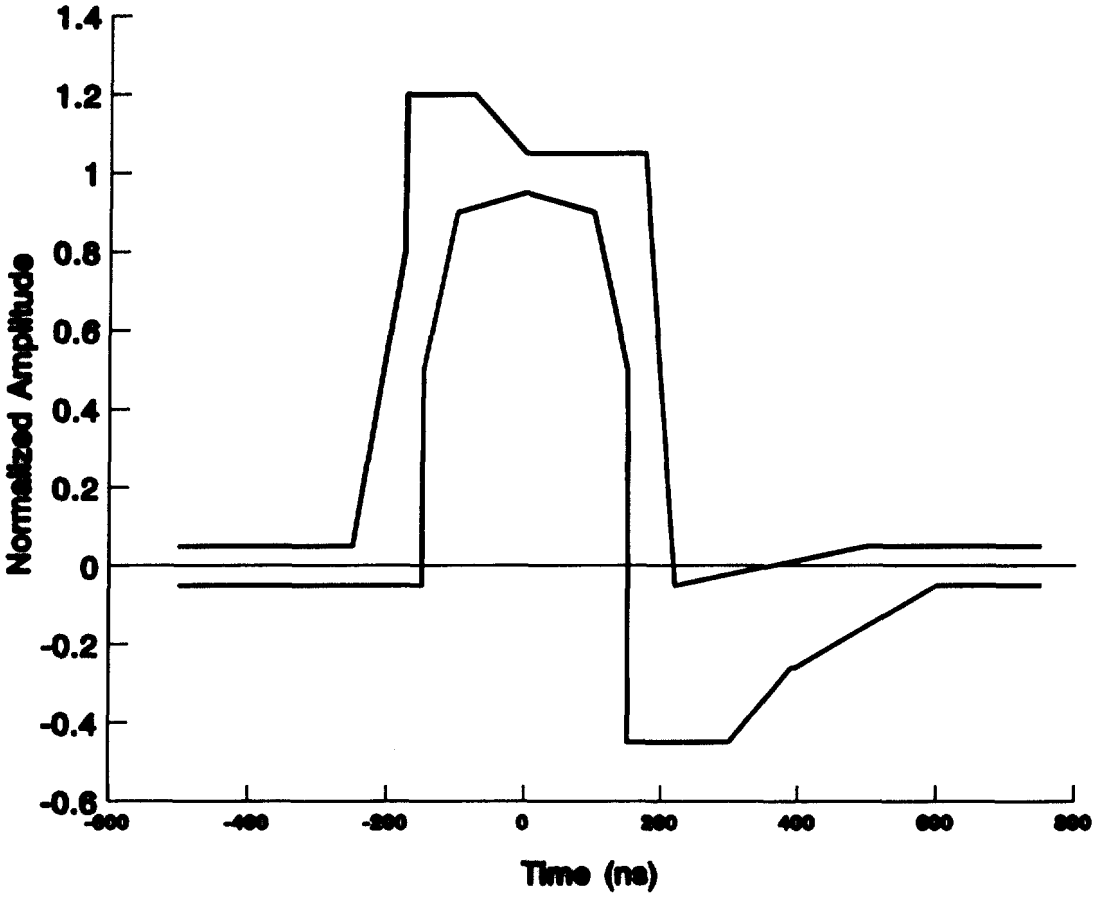
$$\frac{V_{out}}{V_{in}} = \frac{n_2 S^2 + n_1 S + n_0}{d_3 S^3 + d_2 S^2 + d_1 S + d_0}$$

where:

$n_0 = 1.6049 \times 10^{6}$
$n_1 = 7.9861 \times 10^{-1}$
$n_2 = 9.2404 \times 10^{-8}$
$d_0 = 2.1612 \times 10^{6}$
$d_1 = 1.7223$
$d_2 = 4.575 \times 10^{-7}$
$d_3 = 3.8307 \times 10^{-14}$
$S = j 2 \prod f$
$f$ = frequency (Hertz)

(c) *Option C output pulse.* When applied to a 100 Ohm resistor, the

instantaneous amplitude of the output from the registered terminal equipment obtained when Option C is implemented shall fall within the pulse template obtained by passing the pulses obtained in Option B through the transfer function in Option B a second time.




**MAXIMUM CURVE**

| NANO-SECONDS | -500 | -250 | -175 | -175 | -75 | 0 | 175 | 220 | 500 | 750 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NORMALIZED AMPLITUDE | .05 | .05 | .8 | 1.2 | 1.2 | 1.05 | 1.05 | -.05 | .05 | .05 | | |

**MINIMUM CURVE**

| NANO-SECONDS | -500 | -150 | -150 | -100 | 0 | 100 | 150 | 150 | 300 | 396 | 600 | 750 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NORMALIZED AMPLITUDE | -.05 | -.05 | .5 | .9 | .95 | .9 | .5 | -.45 | -.45 | -.26 | -.05 | -.05 |

**Figure 68.308(b) (Ref. EIA/TIA 547-1989)**
**Isolated Pulse Template and Corner Points for 1.544 Mbps equipment**
NOTE: The pulse amplitude is 2.4 to 3.6 V. (Use constant scaling factor to fit normalized template.)

(iii) *Adjustment of signal voltage.* The signal voltage at the network interface must be limited so that the range of pulse amplitudes received at the first telephone company repeater is controlled to ±4 dB. This limitation is achieved by implementing the appropriate output pulse option as a function of telephone company cable loss as specified at time of installation.

| Cable Loss at 772 kHz (dB) | Terminal Equipment | |
|---|---|---|
| | Output Pulse | Loss at 772 kHz |
| 15 to 22 | Option A | 0 |
| 7.5 to 15 | Option B | 7.5 |
| 0 to 7.5 | Option C | 15 |

(iv)
*Output power.* The output power in a 3 kHz band about 772 kHz when an all ones signal sequence is being produced as measured across a 100 Ohm terminating resistance shall not exceed +19 dBm. The power in a 3 kHz band about 1.544 MHz shall be at least 25 dB below that in a 3 kHz band about 772 kHz.

(v) *Encoded Analog Content.* If registered terminal equipment connected to 1.544 Mbps digital service contains an analog-to-digital converter, or generates signals directly in digital form which are intended for eventual conversion into voiceband analog signals, the encoded analog content of the subrate channels within the 1.544 Mbps signal must be limited. The maximum equivalent power of encoded analog signals for other than live voice that are not intended for network control signaling as derived by a zero level decoder test configuration shall not exceed -12 dBm when averaged over any 3-second time interval. The maximum equivalent power of encoded analog signals as derived by a zero level decoder test configuration for signals intended for network control signaling shall not exceed -3 dBm when averaged over any 3-second interval.

**§ 68.310 Transverse balance limitations.**

(a) *Technical Description and Application.* The Transverse Balance$_{m\text{-}l}$, coefficient is expressed as

$$BALANCE_{m\text{-}l} = 20 \log_{10} \frac{e_M}{e_L}$$

Where $e_L$ is the longitudinal voltage produced across a longitudinal termination $Z_l$ and $e_M$ is the metallic voltage across the tip-ring or tip 1 and ring 1 interface of the input port

when a voltage (at any frequency between $f_1$ and < $f_2$, see Table 68.310-1) is applied from a balanced source with a metallic impedance $Z_0$ (see Table 68.310-1). The source voltage should be set such that $e_M$ = E volts (see Table 68.310-1) when a termination of $Z_0$ is substituted for the terminal equipment.

The minimum transverse balance coefficient specified in this section (as appropriate) shall be equalled or exceeded for all 2-wire network ports, OPS line ports and the transmit pair (tip and ring) and receive pair (tip 1 and ring 1) of all 4-wire network ports at all values of dc loop current that the port under test is capable of drawing when attached to the appropriate loop simulator circuit (See 68.3). An illustrative test circuit that satisfies the above conditions is shown in Figure 68.310-1(a) for analog and 68.310-1(b) for digital and subrate; other means may be used to determine the transverse balance coefficient specified herein, provided that adequate documentation of the appropriateness, precision, and accuracy of the alternative means is provided by the applicant.

The minimum transverse balance requirements specified below shall be equalled or exceeded under all reasonable conditions of the application of earth ground to the equipment or protective circuitry under test.

Table 68.310-1(a)

| | Analog Voiceband | Subrate Digital | 1.544 Mbps Digital |
|---|---|---|---|
| Longitudinal Termination - $Z_1$ | 500 Ω | See Table 310-2 | 90 Ω |
| Metallic Source Impedance - $Z_0$ | 600 Ω | 135 Ω | 100 Ω |
| Lower Frequency - $f_1$ | 200 Hz | 200 Hz | 10 kHz |
| Upper Frequency - $f_2$ | 4 kHz | * | 1.544 MHz |
| Metallic Voltage for Test - E | 0.775 V | 0.367 V | 0.316 V |

* The upper frequency equals the digital line rate for the subrate service under test (See Table 68.310(b)).

(b) *Analog Voiceband Equipment.* All registered analog voiceband equipment shall be tested in the off-hook state. The minimum transverse balance requirement in the off-hook state shall be 40 dB, throughout the range of frequencies specified in Table

68.310(a). For some categories of equipment, additional requirements also apply to the on-hook state. When both off-hook and on-hook requirements apply, they are:

| State | Frequency (f) | Balance |
|---|---|---|
| Off-hook | 200 Hz ≤ f ≤ 4000 Hz | ≥ 40 dB |
| On-hook | 200 Hz ≤ f ≤ 1000 Hz | ≥ 60 dB |
| On-hook | 1000 Hz ≤ f ≤ 4000 Hz | ≥ 40 dB |

(i) For analog one-port 2-wire terminal equipment with loop-start, ringdown, or inband signaling or for voiceband metallic channel applications, both off-hook and on-hook requirements apply.

(ii) For analog one port equipment with ground-start and reverse-battery signaling only off-hook requirements apply.

(iii) For analog registered protective circuitry for 2-wire applications with loop-start, ringdown, or inband signaling; or for voiceband metallic channel applications, both off-hook and on-hook requirements apply.

Criteria shall be met with either terminal of the interface to other equipment connected to earth ground. The interface to other equipment shall be terminated in an impedance which will be reflected to the telephone connection as 600 Ohms in the off-hook state of the registered protective circuit, and the interface should not be terminated in the on-hook state. Figure 68.310(b) shows the interface of the protective circuitry being tested and the required arrangement at the interface to other equipment.

(iv) For analog registered protective circuitry with ground-start and reverse-battery signaling only off-hook requirements apply. Criteria shall be met with either terminal of the interface to other equipment connected to earth ground. The interface to other equipment shall be terminated in an impedance which will be reflected to the telephone connection as 600 Ohms in the off-hook state of the registered protective circuit. Figure 68.310(b) shows the interface of the protective circuitry under test and the required arrangement at the interface to the other equipment.

(v) For analog multi-port equipment with loop-start signaling both off-hook and on-hook requirements apply. Criteria shall be satisfied for all ports when all the ports not under test are terminated in their appropriate networks, as will be identified below, and when interface connections other than the ports are terminated in circuits appropriate to that interface. The minimum transverse balance coefficients shall also be

satisfied for all values of dc loop current that the registered equipment is capable of drawing through each of its ports when these ports are attached to the loop simulator circuit specified in these rules. The termination for all ports other than the particular one whose transverse balance coefficient is being measured shall have a metallic impedance of 600 Ohms and a longitudinal impedance of 500 Ohms. Figure 68.310(c) shows this termination.

(vi) For analog multi-port equipment with ground-start and reverse-battery signaling, only off-hook requirements apply. Criteria shall be satisfied for all ports when all ports not under test are terminated in their appropriate networks as will be identified below, and when interface connections other than the ports are terminated in circuits appropriate to that interface. The minimum transverse balance coefficients shall be satisfied for all values of dc loop current that the registered equipment is capable of drawing through each of its ports when these ports are attached to the loop simulator circuit specified in these rules. The terminations for all ports other than the particular one whose transverse balance coefficient is being measured shall have a metallic impedance of 600 Ohms and a longitudinal impedance of 500 Ohms. Figure 68.310(c) shows this termination.

(vii) For analog registered terminal equipment and protective circuitry for 4-wire network ports, both the off-hook and on-hook requirements apply. The pair not under test shall be terminated in a metallic impedance of 600 Ohms. Other conditions are as follows:

(A) For analog registered protective circuitry with loop-start, ground-start, reverse battery, ringdown, or inband signaling; or for voiceband metallic channel applications. Criteria shall be met with either terminal of the interface to other equipment connected to earth ground. The interface to other equipment shall be terminated in an impedance that will result in 600 Ohms at each of the transmit and receive pairs of the 4-wire telephone connection in the off-hook state of the registered protective circuit, and the interface should not be terminated in the on-hook state. Figure 68.310(d) shows the interface of the protective circuitry being tested and the required arrangement at the interface to other equipment.

(B) For analog multiport equipment with loop start, ground start, and reverse battery, ringdown, or inband signaling; or for voiceband metallic channel applications. Criteria shall be satisfied for all network ports when all the ports not under test are terminated as defined below, and when interface connections other than the network ports are terminated in circuits appropriate to the interface. The criteria shall also be satisfied for all values of dc loop current that when the port is connected to the appropriate 4-wire loop simulator circuit. The terminations for both pairs of all network ports not under test shall have a metallic impedance of 600 Ohms and a longitudinal impedance of 500 Ohms. Figure 68.310(c) shows this termination.

(viii) For analog PBX equipment (or similar systems) with class B or class C off-premises interfaces, only off-hook requirements apply. Criteria shall be satisfied for all off-premises station interface ports when these ports are terminated in their appropriate networks for their off-hook state, and when all other interface connections are terminated in circuits appropriate to that interface. The minimum transverse balance coefficients shall also be satisfied for all values of dc loop current that the registered PBX is capable of providing through off-premises station ports when these ports are attached to the off-premises line simulator circuit specified in these rules.

(ix) For Type Z equipment with loop-start signaling, both off-hook and on-hook requirements apply. Equipment which has on-hook impedance characteristics which do not conform to the requirements of § 68.312 (e.g., Type Z), shall comply with minimum transverse balance requirements of 40 dB in the voiceband. See § 68.312(h) for conditions upon registration of "Type Z" equipment.

(c) *Digital Equipment.* The minimum transverse balance requirements for registered terminal equipment connected to digital services shall be equalled or exceeded for the range of frequencies applicable for the equipment under test and under all reasonable conditions of the application of earth ground to the equipment. All such terminal equipment shall have a transverse balance in the acceptable region of Figure 68.310(e) for the range of frequencies shown in Table 68.310(b) for the specified digital service in question. The metallic impedance used for the transverse balance measurements for all subrate services shall be 135 Ohms and for 1.544 Mbps shall be 100 Ohms. The longitudinal termination for subrate services shall be as defined in Table 68.310(b) and 1.544 Mbps shall be 90 Ohms.

Table 68.310(b)

Frequency Ranges of Transverse Balance Requirements for Digital Services

| Digital Service | Frequency Range | Longitudinal Termination | Metallic Termination |
|---|---|---|---|
| 2.4 | 200 to 2.4 kHz | 500 | 135 |
| 3.2 | 200 to 3.2 kHz | 500 | 135 |
| 4.8 | 200 to 4.8 kHz | 500 | 135 |
| 6.4 | 200 to 6.4 kHz | 500 | 135 |
| 9.6 | 200 to 9.6 kHz | 500 | 135 |
| 12.8* | 200 to 12.8 kHz | 500/90 | 135 |
| 19.2* | 200 to 19.2 kHz | 500/90 | 135 |
| 25.6* | 200 to 26.6 kHz | 500/90 | 135 |
| 56* | 200 to 56 kHz | 500/90 | 135 |
| 72* | 200 to 72 kHz | 500/90 | 135 |
| 1.544 | 10 kHz to 1.544 MHz | 90 | 100 |

* NOTE: For 200 to 12 kHz the longitudinal termination shall be 500 Ohms and above 12 kHz the longitudinal termination shall be 90 Ohms.

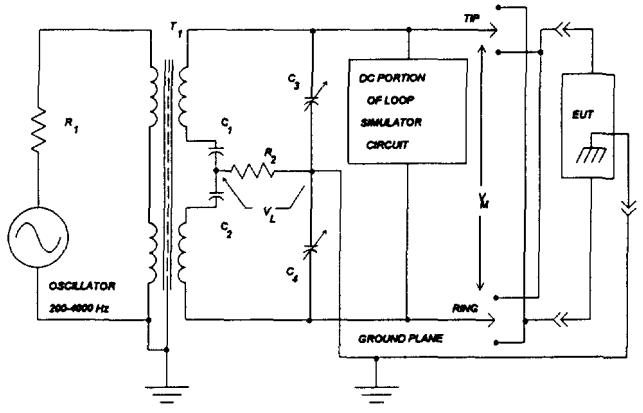



**Figure 68.310-1(a)**
**Illustrative Test Circuit for Transverse Balance (Analog)**

$T_1$ 600 Ω:600 Ω split audio transformer
$C_1$, $C_2$ 8 $\mu$F, 400 V dc, matched to within 0.1 %
$C_3$, $C_4$ 100 to 500 pF adjustable trimmer capacitors
Osc. Audio oscillator with source resistance $R_1$ less than or equal to 600 Ohms
$R_1$ Selected such that $Z_{osc} + R_1 = 600\ \Omega$
$R_2$ 500 Ω

NOTES:
1. $V_M$ should not be measured at the same time as $V_L$
2. Use trimmer capacitors $C_3$ and $C_4$ to balance the test circuit to 20 dB greater balance than the equipment standard for all frequencies specified, with a 600 Ohm resistor substituted for the equipment under test.
3. Exposed conductive surfaces on the exterior of the equipment under test should be connected to the ground plane for this test.
4. When the Terminal Equipment makes provision for an external connection to ground (G), the Terminal Equipment shall be connected to ground. When the Terminal Equipment makes no provision for an external ground, the Terminal Equipment shall be placed on a ground plane which is connected to ground and has overall dimensions at least 50 % greater than the corresponding dimensions of the Terminal Equipment. The Terminal Equipment shall be centrally located on the ground plane without any additional connection to ground.